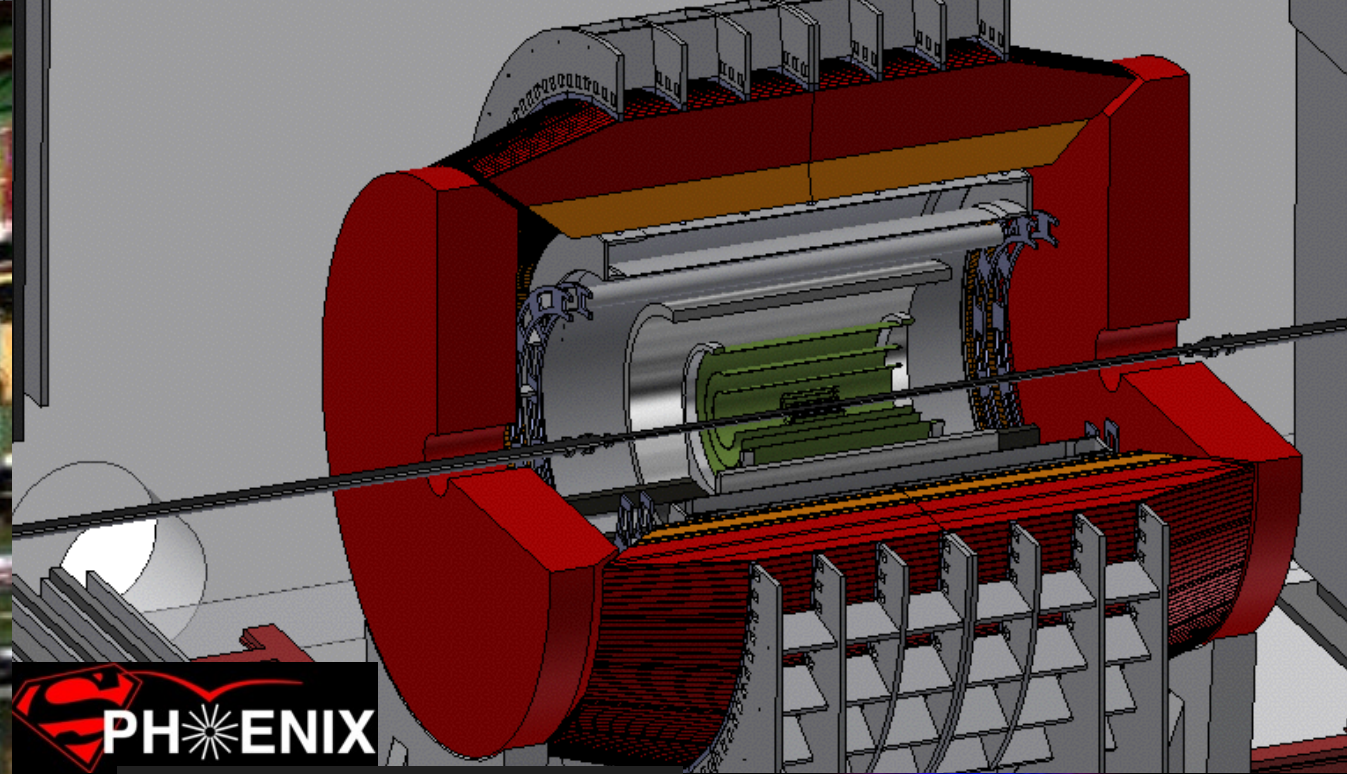
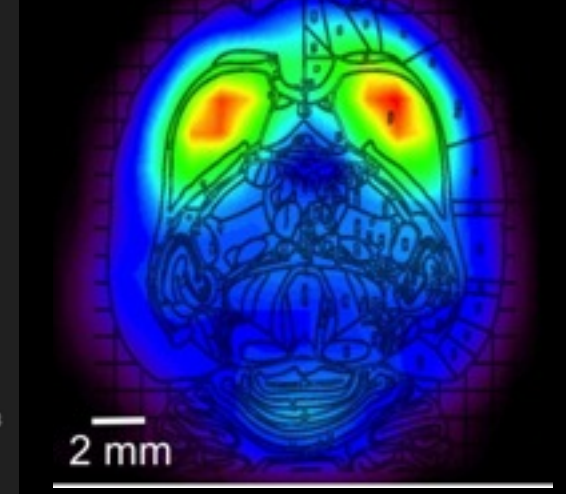
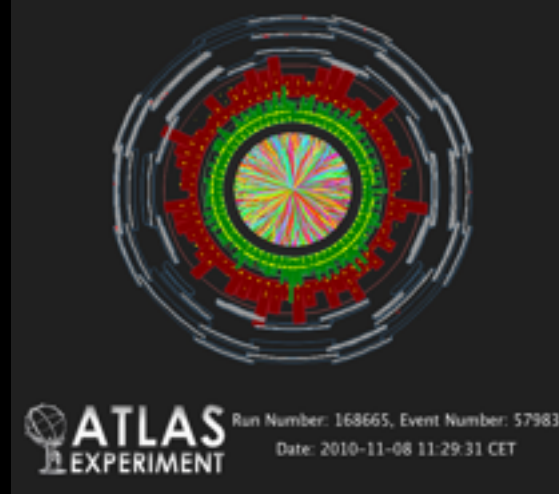


# BNL/PHENIX group

PETER STEINBERG, BNL, SEPTEMBER 10, 2014



 PHENIX



# Primary roles of BNL/PHENIX group

- Primary responsibility of PHENIX group in the BNL physics department is the operational, technical, and administrative support of the PHENIX experiment and the pursuit of physics research with the PHENIX detector
- The group also hosts research with the ATLAS detector at the LHC, and has supported the development of new detectors for positron-emission tomography (PET)
- An increasing fraction of the group's effort is moving toward design, prototyping and performance studies of the sPHENIX detector



# BNL/PHENIX in PHENIX organization

- Co-spokesperson - David Morrison
- Director of operations - Mickey Chiu
  - Transition from Ed O'Brien, to be complete in October
- Deputy director of operations - John Haggerty
- Executive council
  - John Haggerty, David Morrison (ex-officio), Ed O'Brien (ex-officio)
- Detector council
  - Achim Franz, Edward Kistenev
- Technical coordination
  - Martin Purschke (DAQ), Don Lynch (Chief Engineer), Sasha Bazilevsky (Trigger Coordinator)
- Topical group coordinators
  - Gabor David (photons/neutral hadrons), Mickey Chiu (MPC)

# BNL/PHENIX group operations responsibilities

- Operation of PHENIX experimental facility and collaboration management
  - Membership in PHENIX management group, executive and detector councils
  - Coordination of physics run activities
  - All PHENIX detector and support system ES&H and work planning
  - Operation of local PHENIX office for visitor support (250 visitors/year)
  - Coordination of all experiment activities and publications
  - Data production and processing
  - Management, coordination, and participation in all shutdown work
    - Annual detector maintenance
    - Installation and commissioning of upgrade projects



# BNL/PHENIX group operations responsibilities

- Responsibility for specific detector subsystems
  - Electromagnetic calorimeter
  - Silicon vertex barrel (VTX)
  - Silicon forward vertex (fVTX)
  - Zero Degree Calorimeter/Shower max detector
  - Spectrometer magnets
  - Muon piston calorimeters (MPC)
  - Muon piston calorimeter extension (MPC-EX)
  - Data Acquisition
  - Online and offline computing

# BNL/PHENIX group operations responsibilities

- Maintenance of PHENIX common subsystems
  - Safety systems
  - LV/HV systems
  - General computing and databases
  - Electronics control and timing
  - Gas systems
  - Cooling systems
- Supply of consumables
  - Gas, data media, software licenses, spare parts, etc.

# PHENIX group makeup

- 20 PhD scientific staff
  - +A. Bazilevsky, shared with spin group
- 9 technicians
- 3 engineers (mechanical and electrical)
- 3 computing professionals
- 3 physics associates
- 2 administrative assistants
- **11.9 FTE** on research, **27.5 FTE** on operations



# Electronics support staffing level & needs

- Steve Boose plays primary role, along with Sal Polizzo and Mike Lenz
- Eric Mannel hired in 2012 for support of the PHENIX VTX and fVTX detectors
  - This satisfied a critical need within the experiment and his addition to the group has been a great success

# Staffing plans

- In 2013/2014, BNL/PHENIX group made two scientific staff hires
  - Dennis Perepelitsa, postdoc - Goldhaber fellow
    - Research on ATLAS, continuing thesis work on jets in p+Pb
    - Research on PHENIX, continuing work on jets in d+Au, new work on neutral pions in d+Au, and development work on sPHENIX (b-tagging, pp triggering)
  - Jin Huang, staff physicist
    - PHENIX detector support on VTX/fVTX, spin research
    - sPHENIX forward magnet design
    - sPHENIX EMCal design
    - Continued research work at JLab (SoLID collaboration)
- In 2012, added Eric Mannel for support on f/VTX

# Staffing plans

- After departure of Anne Sickles for UIUC, have made request to department for
  - New postdoc
  - New staff hire
- Wide range of opportunities for contributions to PHENIX p+A/He3+A, sPHENIX design and R&D, ATLAS HI research
- Brant Johnson now at 80%
  - Reducing to 60% by next year



# BNL/PHENIX physics research efforts

PHOTONS/  
NEUTRAL  
HADRONS

PHENIX  
P+P/D+AU/AU+AU

ATLAS  
PB+PB/P+PB

JETS

PHENIX  
D+AU

ATLAS  
P+PB/PB+PB

HADRON  
CORRELATIONS

PHENIX  
D+AU

ATLAS  
P+PB/PB+PB

SOFT PHYSICS/  
ENERGY SCAN

PHENIX  
P+P/D+AU/AU+AU

excellent synergy  
between different  
parts of program

DETECTOR  
R&D

PHENIX MPC-EX  
SPHENIX

# FY13-14 research highlights

- PHENIX
  - Neutral mesons and direct photons in p+p, d+Au, Au+Au
    - Initial state effects, jet energy loss, forward physics with MPC, dark photons
  - Transverse energy distributions
    - Constituent quark scaling
  - Correlations in d+Au - evidence for collectivity at RHIC
- ATLAS
  - Comprehensive study of flow phenomena in Pb+Pb & p+Pb
  - Jets and photons in Pb+Pb & p+Pb
- sPHENIX
  - Construction and test beams for calorimeter prototypes
  - Progress toward updated MIE

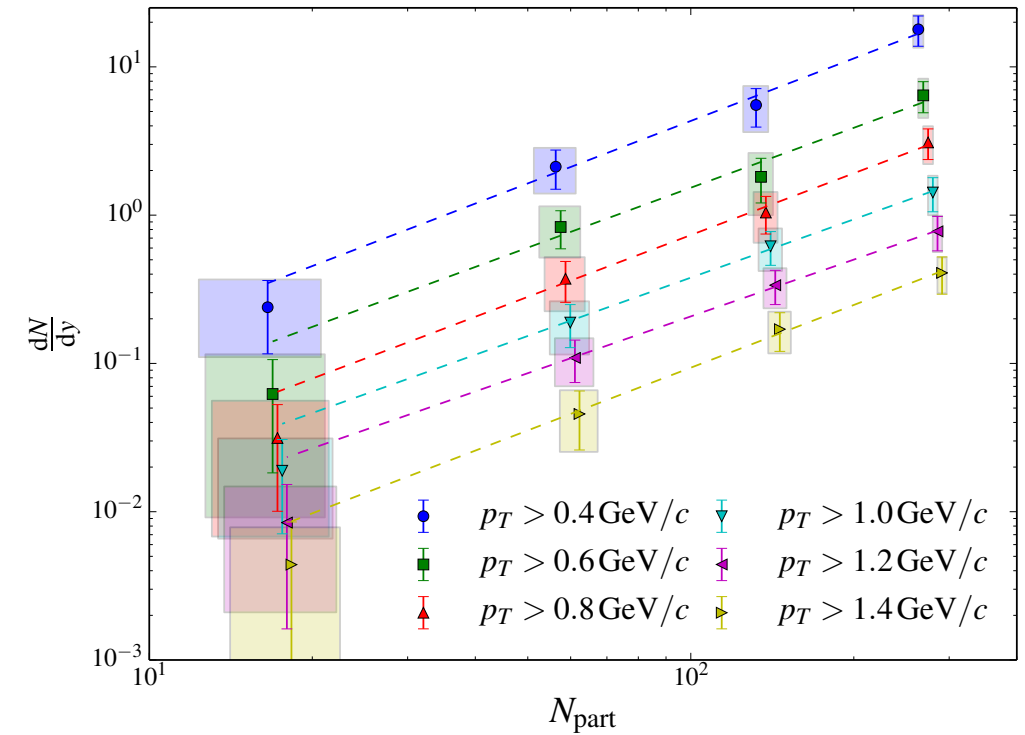
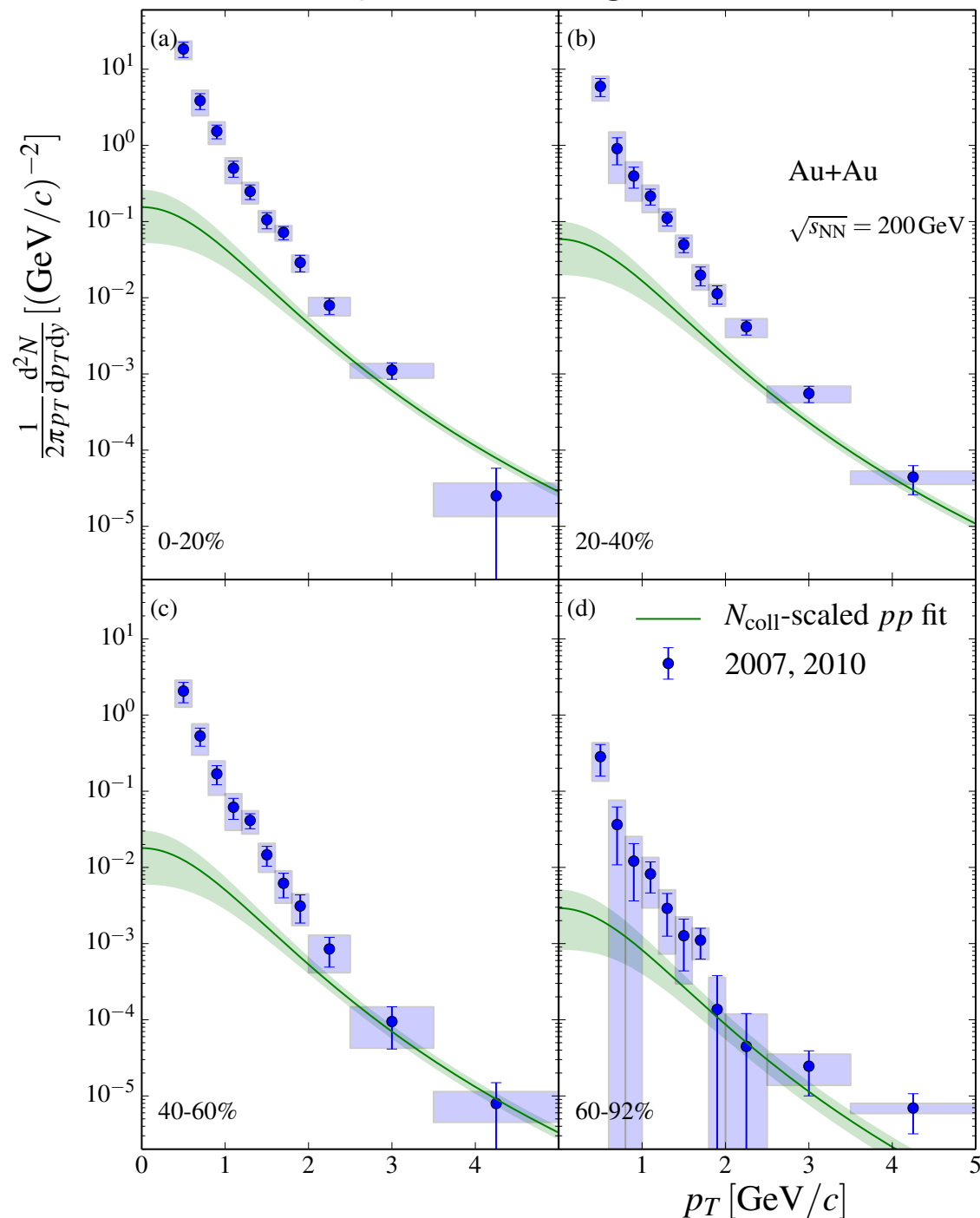
# BNL/PHENIX group physics output

- 24 publications submitted in FY2014
- PHENIX group members were among the primary authors of 11 of these
- Soft physics in d+Au and Au+Au
  - Transverse energy distributions
  - Centrality in d+Au
  - HBT in d+Au and Au+Au
  - Long range correlations in d+Au
- Photons and neutral mesons
  - Centrality dep. of direct photons in Au+Au
  - Dark photons
  - Photon  $v_2$  and  $v_3$
- Spin
  - Double helicity asymmetries for  $\pi^0$  and  $\eta$
  - Single spin asymmetry of  $\eta$  mesons
  - Single spin asymmetries at mid and forward rapidity
- Detector development and design
  - fVTX NIM article
  - EIC detector concept white paper



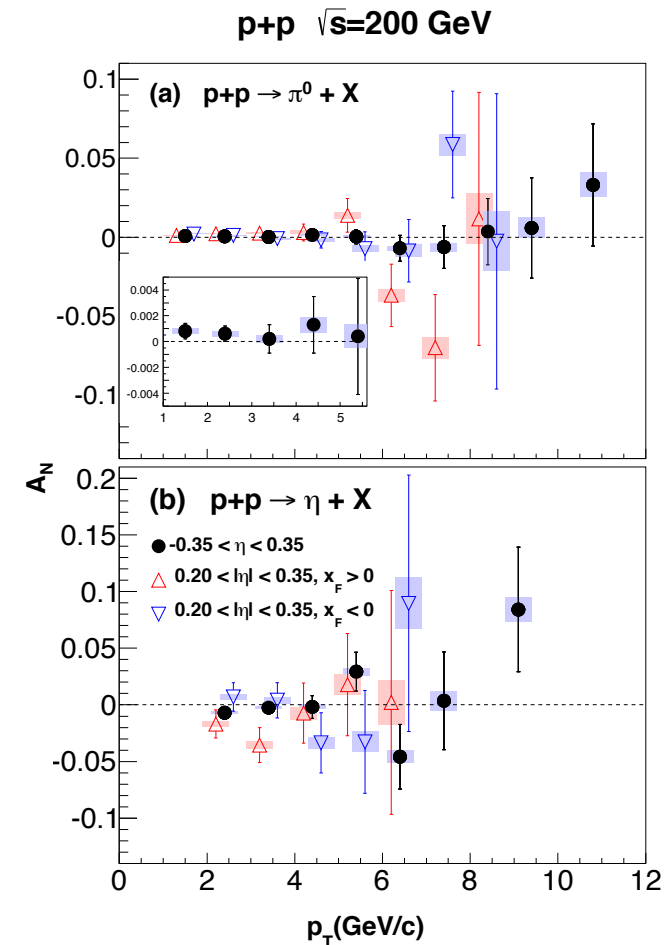
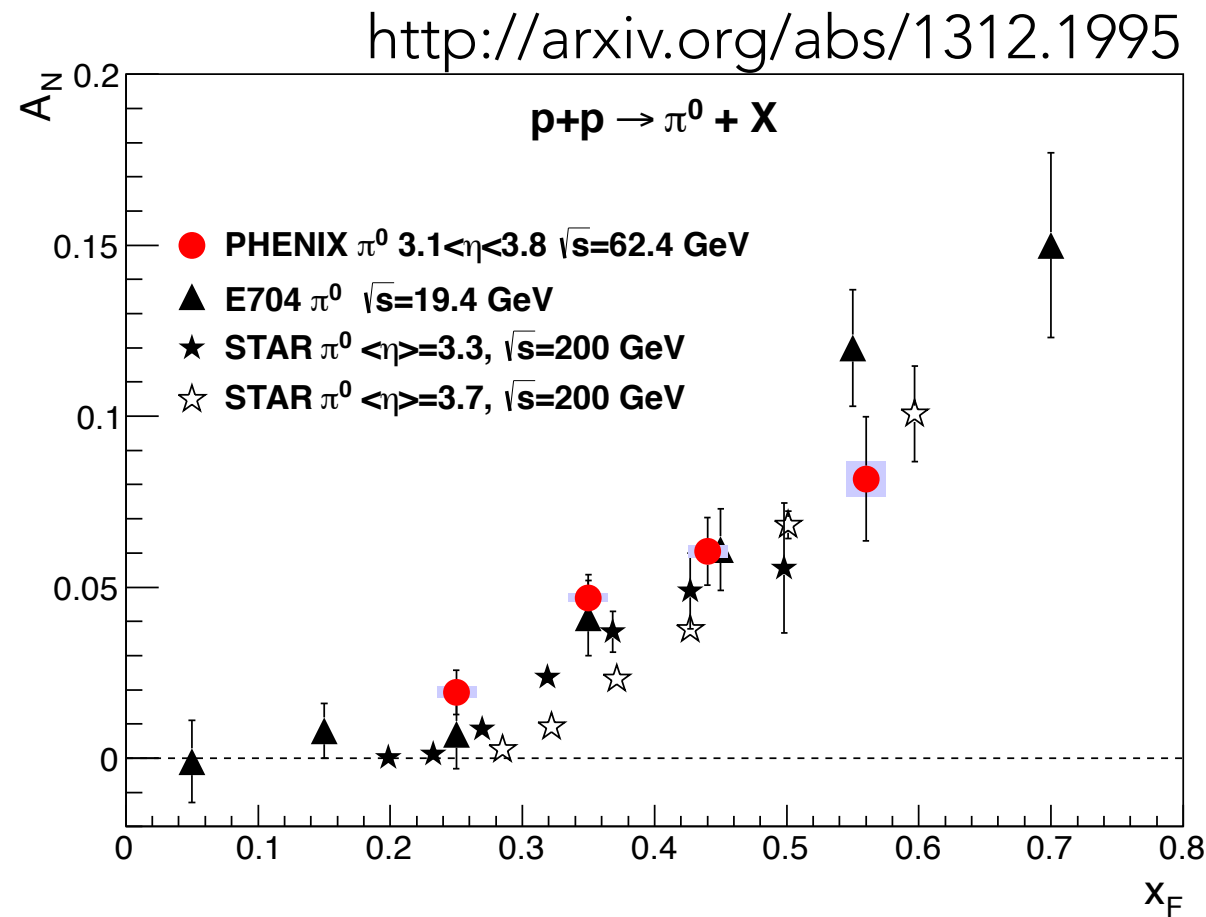
# Direct photon production in Au+Au (David)

<http://arxiv.org/abs/1405.3940>



Clear excess observed over  
pp at low  $p_T$ , yield scales  
 $\sim N_{\text{part}}^\alpha$  with  $\alpha \sim 1.5$ , will  
provide constraints to  
modeling of space-time evolution

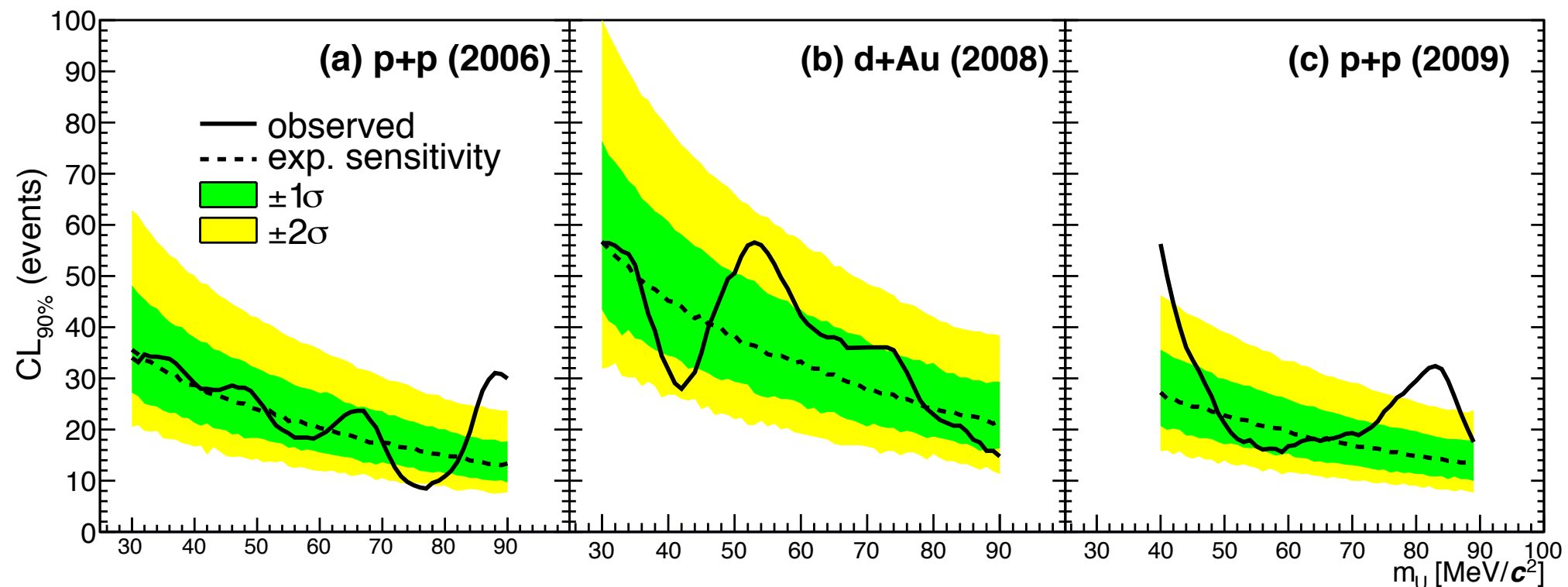
# Single spin asymmetries of neutral pions at midrapidity and forward angles (Chiu)



Combined with BRAHMS forward charged pions,  
these data rule out Sivers effect  
as source of observed transverse asymmetries

# Dark photon limit (Morrison)

<http://arxiv.org/abs/1409.0851>



Several existing experimental anomalies (g-2, lamb shift in muonic hydrogen, positron excess in cosmic rays) all potentially explained by "dark photon", mixing with real photons

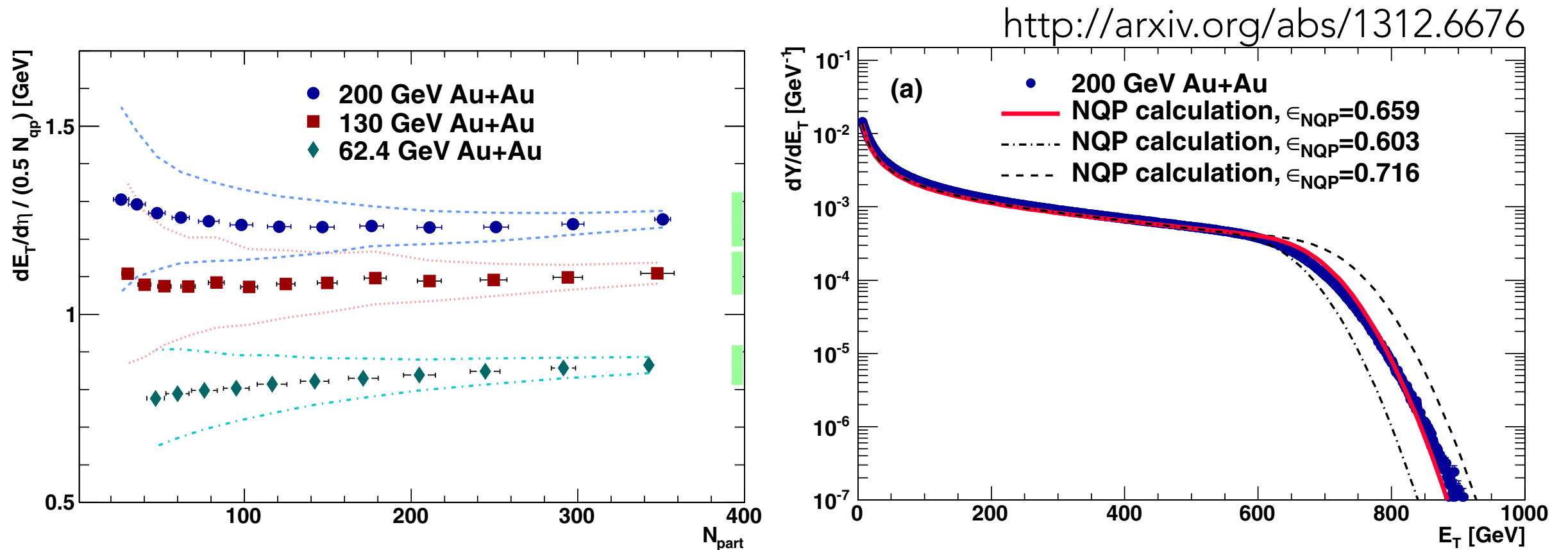
Search performed in Dalitz decays of neutral mesons in p+p and d+Au.

Observed yield consistent with background fluctuations at  $2\sigma$  level, so translated into upper limit on coupling strength  $\epsilon^2$

Morrison adapted the CLs technique (current state of the art) to PHENIX from the HEP community to determine the 90% CL upper limit



# Quark participant scaling (Tannenbaum, Mitchell)

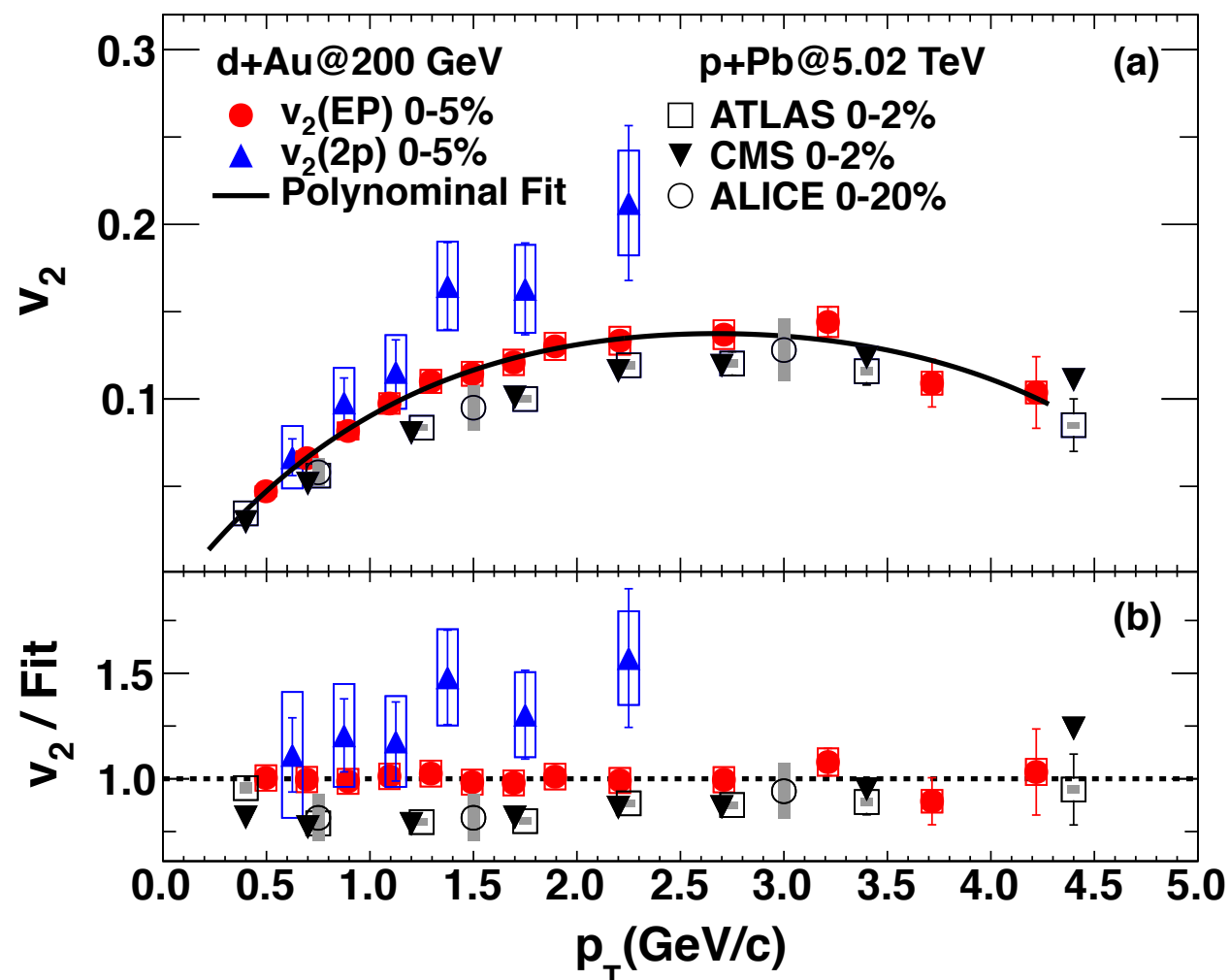


Convolving p+p distributions (after correction for trigger/selection efficiency), based on linear scaling of p+p data with the number of "quark participants" describes measured  $E_T$  distribution in Au+Au

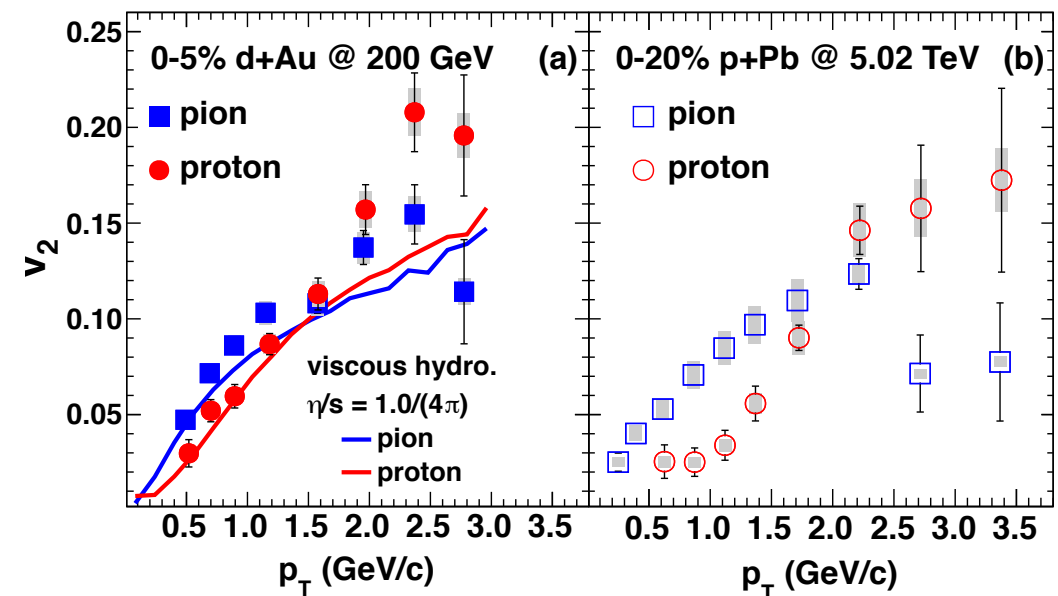
Simple approach, which incorporates composite nature of nucleon, to quantitatively model soft particle production at  $\eta=0$  in detail.

# Collectivity in d+Au

After discovery of  $v_2$ -like anisotropies with 2PC p+Pb at LHC (ALICE, ATLAS [Jia, Steinberg]), PHENIX measured similar behavior in d+Au collisions (Sickles)



<http://arxiv.org/abs/1404.7461>



Updated measurements (involving Jia and Sickles), using event plane method (measured in MPC) confirm original results qualitatively, and show clear mass splitting.

# BNL/PHENIX contributions to ATLAS HI

- Three members of the group contribute to ATLAS HI
  - Steinberg, Jia (joint with SBU), Perepelitsa
  - Steinberg was HI physics convenor from 10/2008-10/2011
  - Jia is incoming HI convenor as of 10/2014
- Physics contributions in FY2013-14
  - Jia - systematics of collective flow in p+Pb and Pb+Pb
    - Event plane correlations, event engineering
  - Steinberg - Photon production in Pb+Pb (QM14), ongoing work on photons in p+Pb
  - Perepelitsa - inclusive jet production in p+Pb (QM14), contributions to Pb+Pb inclusive jets.

# BNL/PHENIX contributions to ATLAS HI

"Centrality and rapidity dependence of inclusive jet production in  $\sqrt{s_{NN}} = 5.02$  TeV proton-lead collisions with the ATLAS detector", ATLAS-CONF-2014-024 (Perepelitsa and Steinberg [who proposed p scaling])

"Measurements of the nuclear modification factor for jets in Pb+Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV with the ATLAS detector", ATLAS-CONF-2014-025 (Perepelitsa)

"Measurement of event-plane correlations in  $\sqrt{s_{NN}}=2.76$  TeV lead-lead collisions with the ATLAS detector", **Physical Review C 90 (2014) 024905** (Jia)

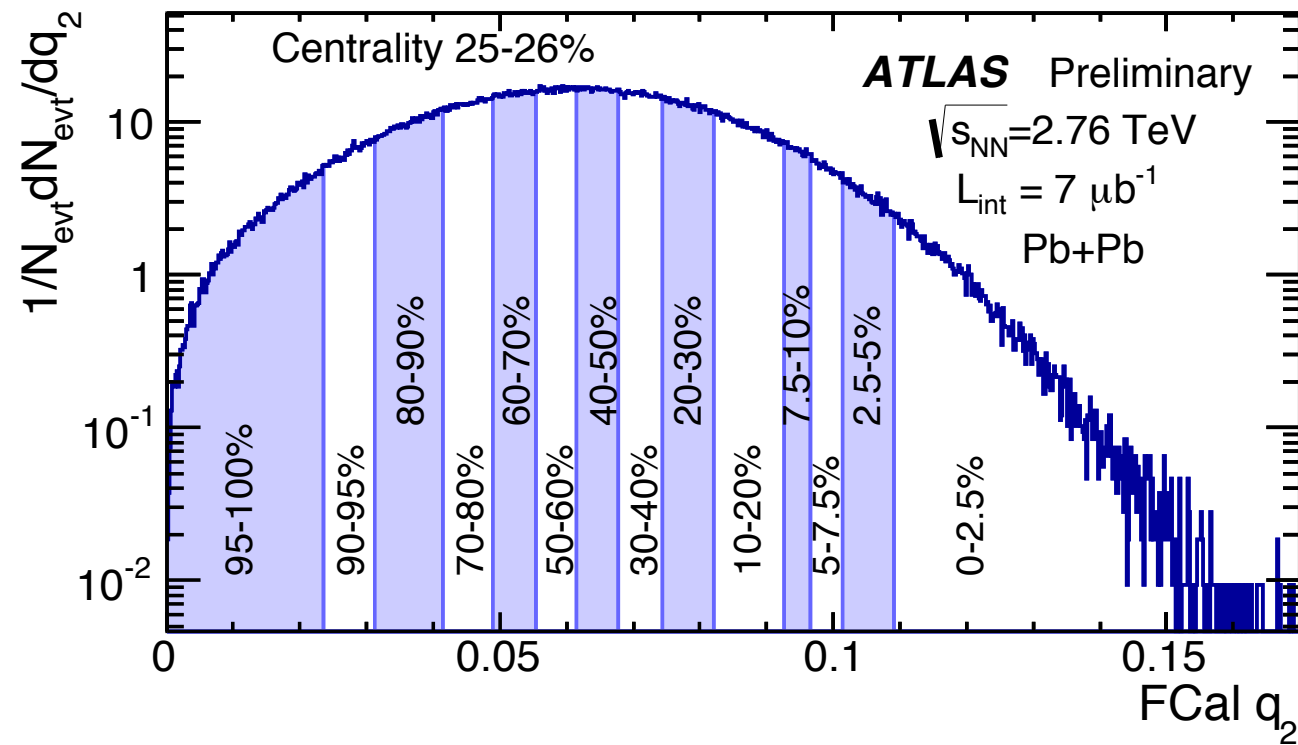
"Measurement of the correlation between elliptic flow and higher-order flow harmonics in lead-lead collisions at  $\sqrt{s_{NN}}=2.76$  TeV", ATLAS-CONF-2014-022 (Jia)

"Measurement of long-range pseudorapidity correlations and azimuthal harmonics in  $\sqrt{s_{NN}}=5.02$  TeV proton-lead collisions with the ATLAS detector", <http://arxiv.org/abs/1409.1792> (Jia) **NEW!**

Centrality, rapidity and  $p_T$  dependence of isolated prompt photon production in lead-lead collisions at  $\sqrt{s_{NN}} = 2.76$  TeV with the ATLAS detector at the LHC, ATLAS-CONF-2014-026 (Steinberg)

## Publications and public CONF notes.

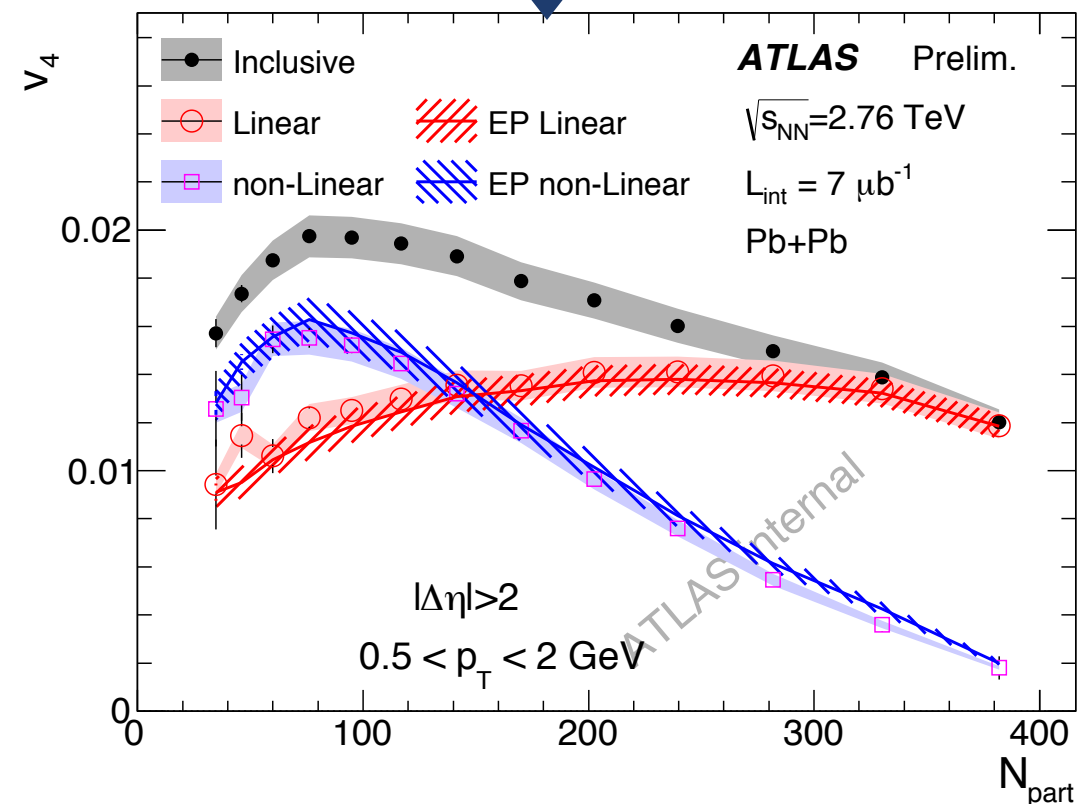
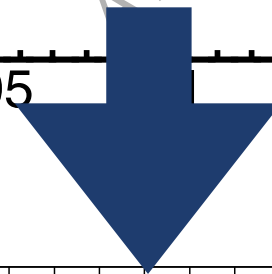
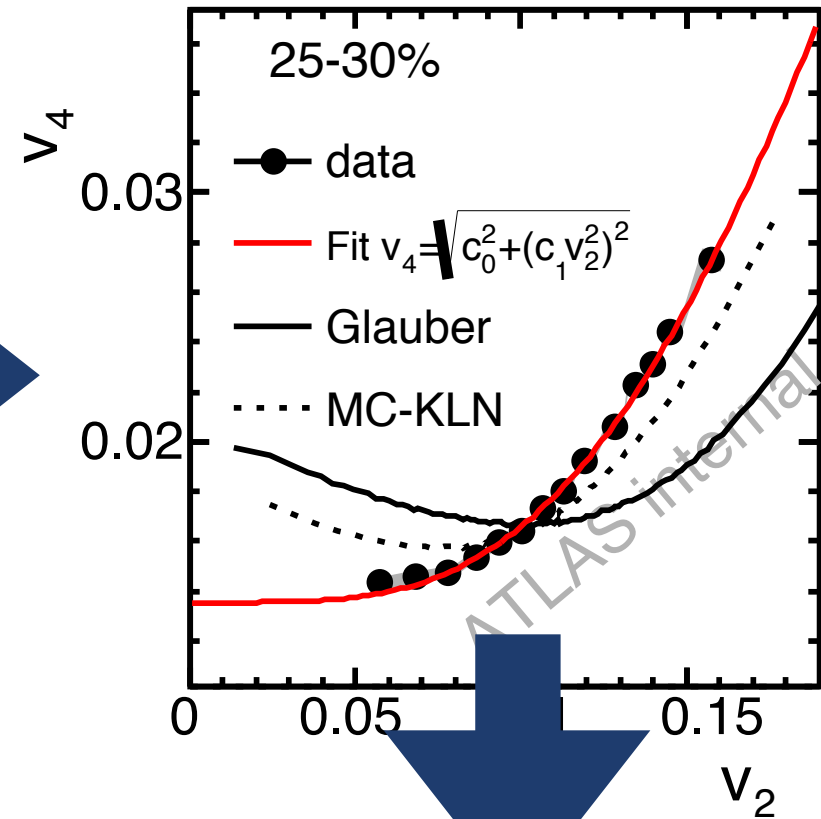
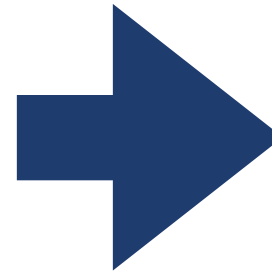
# Event engineering



Very powerful technique,  
 able to directly extract  
 contributions from non-linear  
 coupling between harmonics

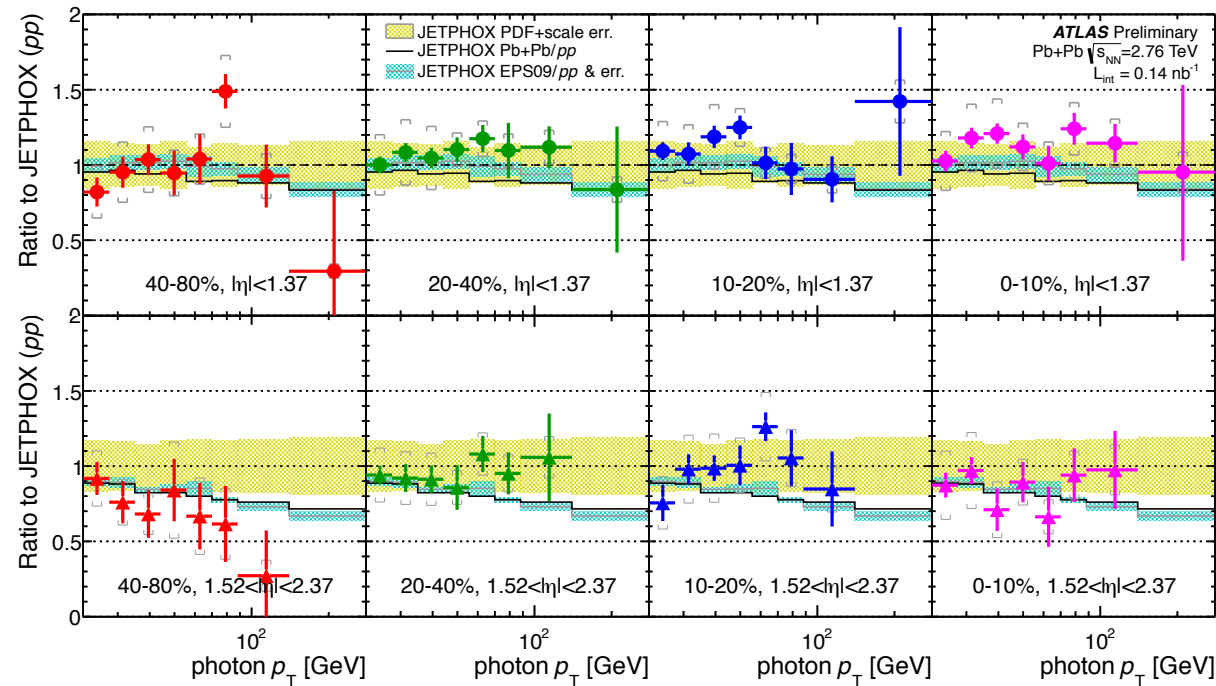
$$v_4 = \sqrt{c_0^2 + (c_1 v_2^2)^2}$$

$$v_4^L = c_0, \quad v_4^{NL} = \sqrt{v_4^2 - c_0^2}$$

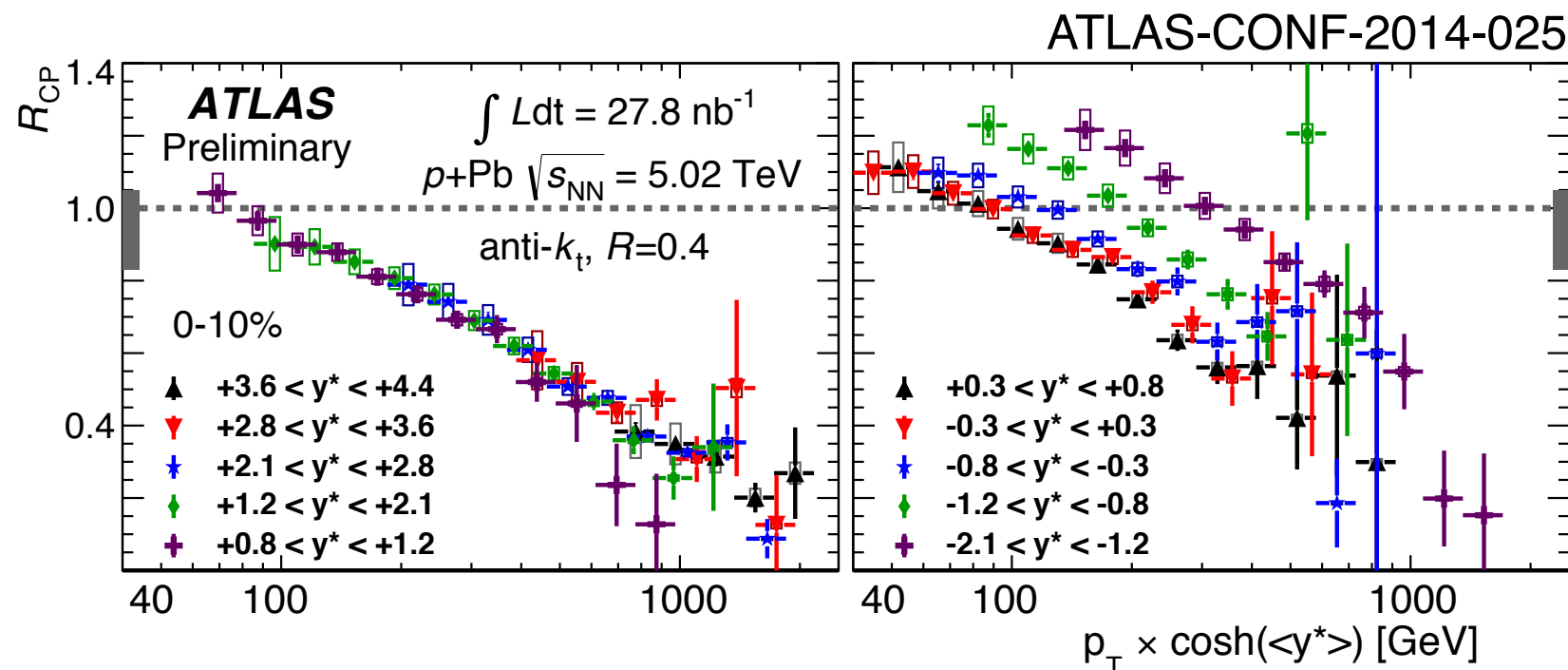


# Jets and Photons at QM14

ATLAS-CONF-2014-026



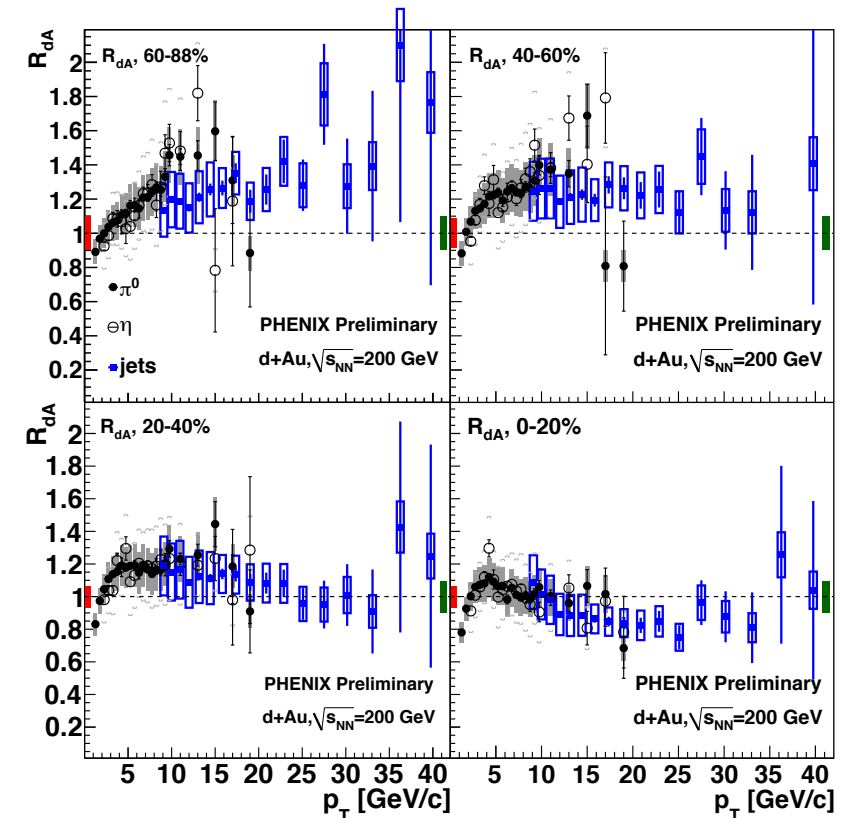
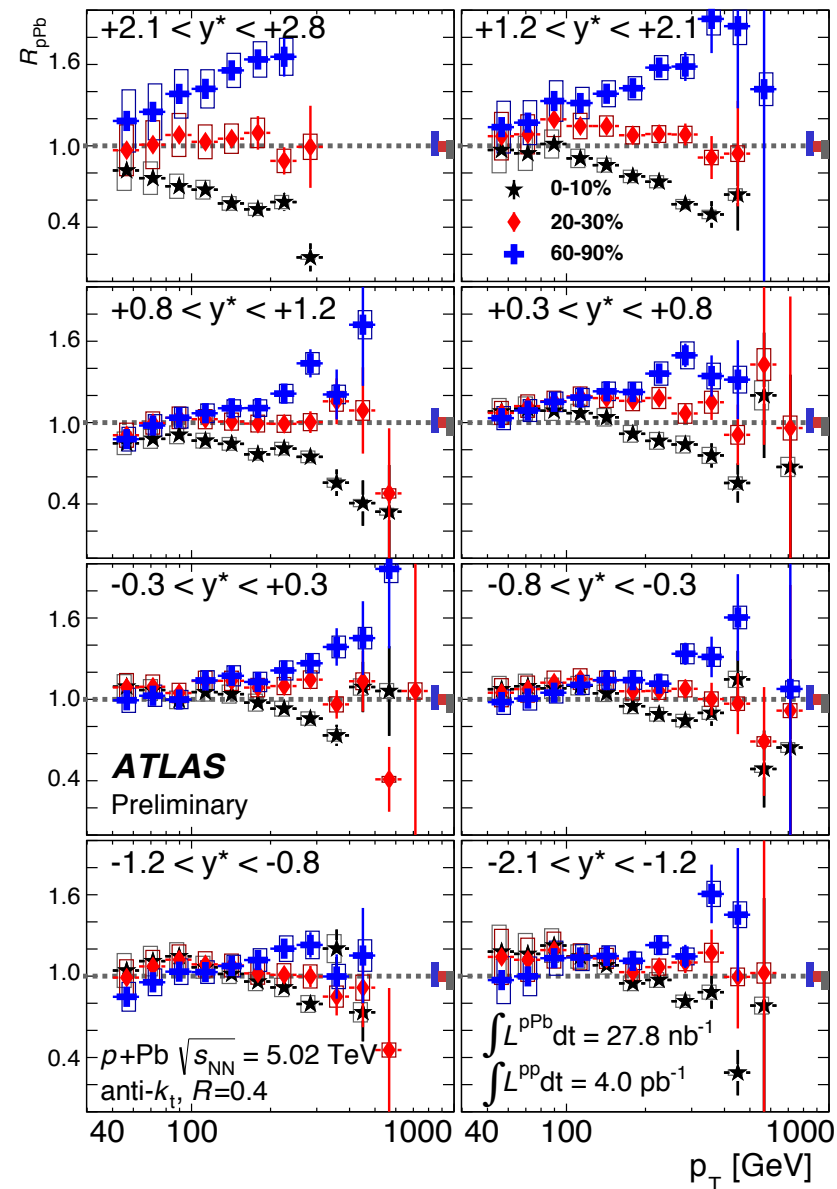
Photon production in Pb+Pb consistent with pQCD calculations both for pp and EPS09



Jet production in minbias p+Pb consistent with expectations but  $R_{CP}$  highly suppressed, and scales (non-trivially!) with jet energy



# Synergy of LHC and RHIC results

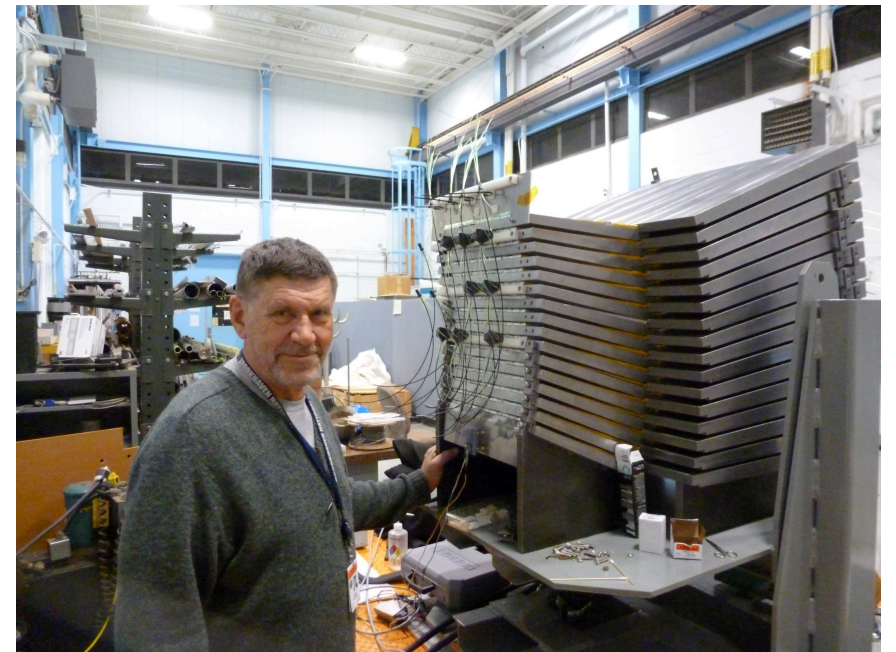


Similar, unexpected “splitting” of central & peripheral suppression factors seen both at RHIC and LHC: generating substantial interest in theory (Bathe et al, Alvioli, Strikman, et al) and will be basis of new measurements (PHENIX p+A, with MPC-EX installed)

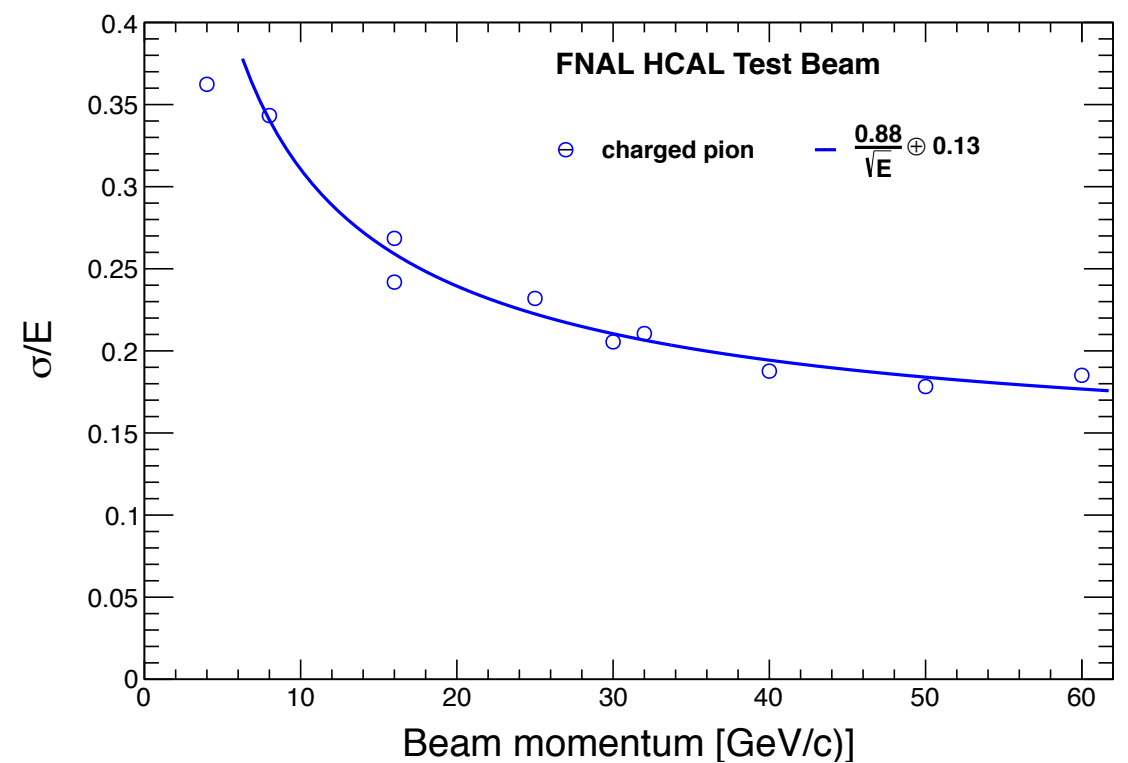
# BNL/PHENIX sPHENIX involvement

- For details on sPHENIX project, see Ed O'Brien's talk
- Group has major involvement in sPHENIX project
  - Project management: Haggerty, O'Brien
  - Oversight: Haggerty, O'Brien, Morrison
  - Detector design and construction: Woody, Kistenev, Huang
  - Planning documents for sPHENIX, fsPHENIX, "ePHENIX": Morrison, Haggerty, Huang, Woody, Franz, Pinkenburg
  - Physics studies: Sickles (jets), Perepelitsa, Steinberg (b-jets)

# FNAL sPHENIX/EIC testbeam, Feb 2014



Major involvement from BNL/PHENIX group:  
design, construction, readout, etc.  
Important for selecting technologies  
for sPHENIX (e.g. SPACAL over tilted plate),  
and characterizing energy resolution





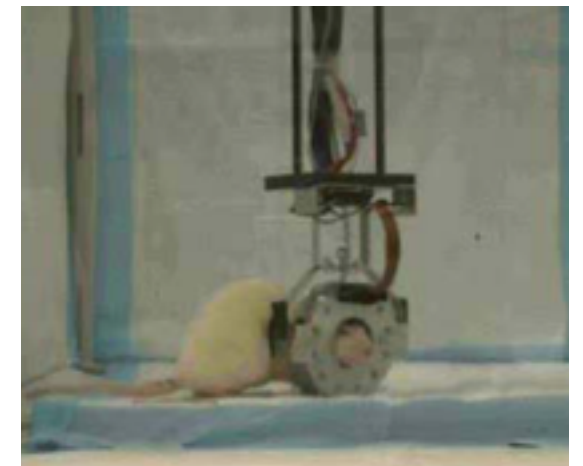
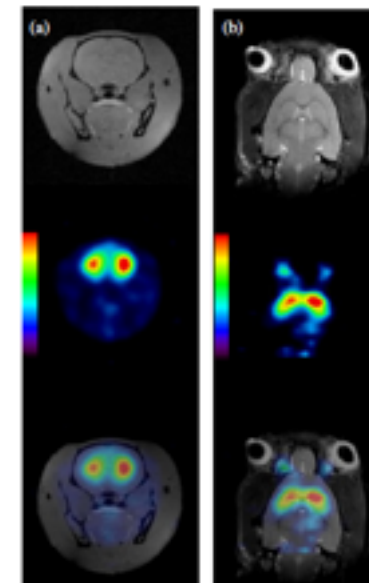
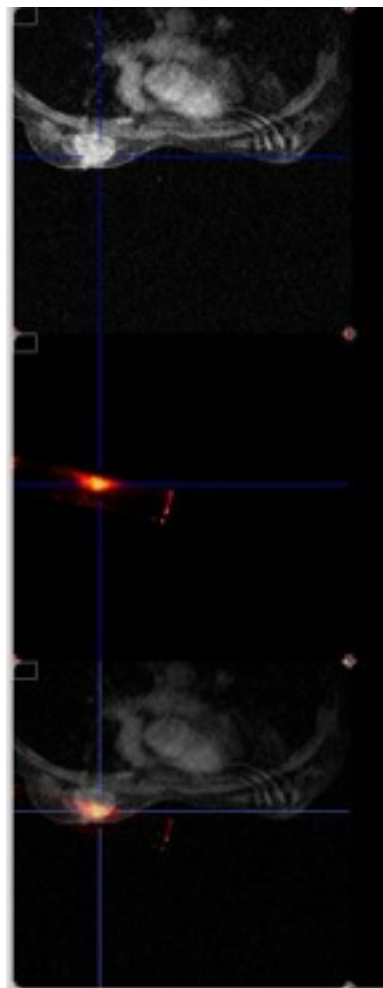
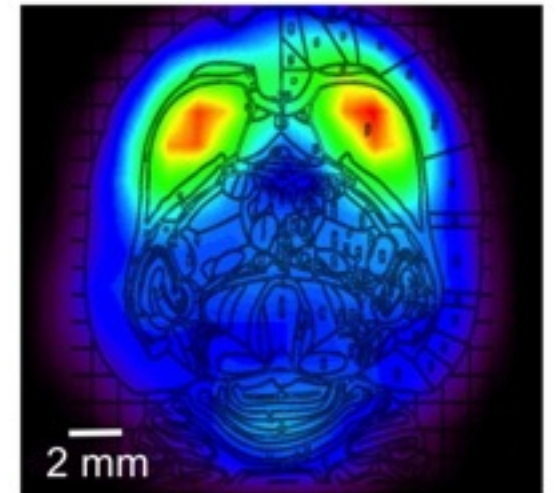
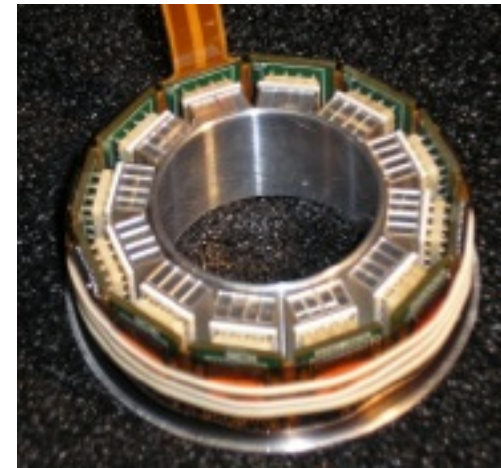
# EIC R&D work

- Members of the group are involved in EIC R&D work
- eRD6
  - Azmoun, Pak, Purschke, Woody (GEM TPC & DAQ support)
- eRD11
  - Huang (Aerogel RICH)
- eRD10
  - Chiu (PI, 10 ps TOF)

# Connections with Other Technologies – Medical Imaging

## Rat Conscious Animal PET (RatCAP)

- First brain images of live rats without the use of anesthesia
- Simultaneous high resolution PET-MRI
- First simultaneous PET-MRI human scan using dedicated breast MRI scanner



**Nature Methods Vol.8,  
No.4 (2011) 347-352**

**Phys. Med. Biol. 56 (2011)  
2458-2480**

Now being commercialized  
by startup on Long Island:



Detectors developed in the BNL Physics Department  
PHENIX Group (C.Woody, M.Purschke, S.Stoll) provide major input

# Summary

- Very active time for BNL/PHENIX group, with group members active in several projects
- PHENIX
  - Physics output remains strong, with strength in soft physics, correlations in d+Au, photon/ $\pi^0$
- ATLAS
  - Making strong contributions in collective flow, jets in Pb+Pb and p+Pb, and photons in Pb+Pb
- sPHENIX
  - Important role in management, design, computing and physics studies
- Detector R&D
  - Medical imaging, sPHENIX, EIC

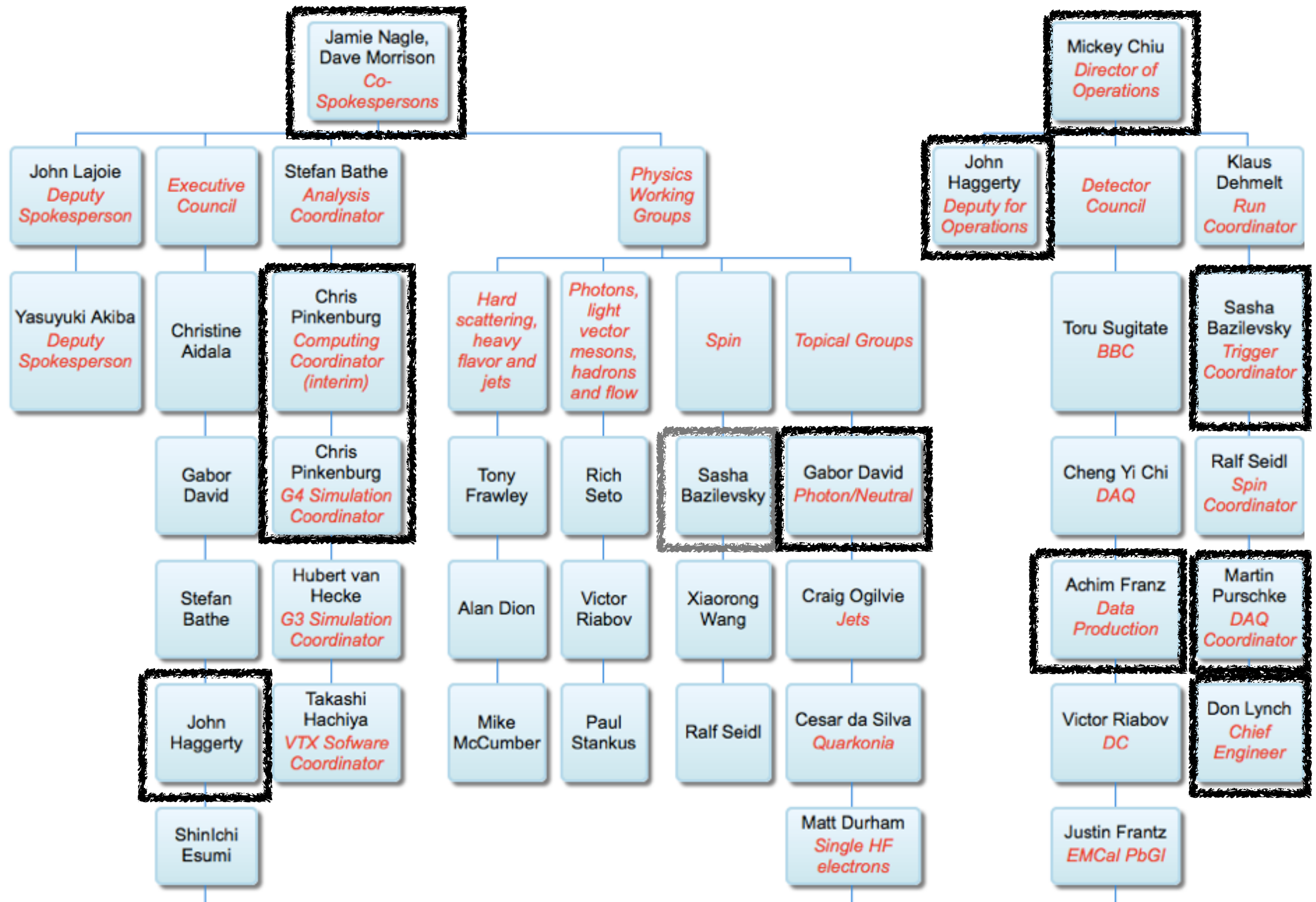


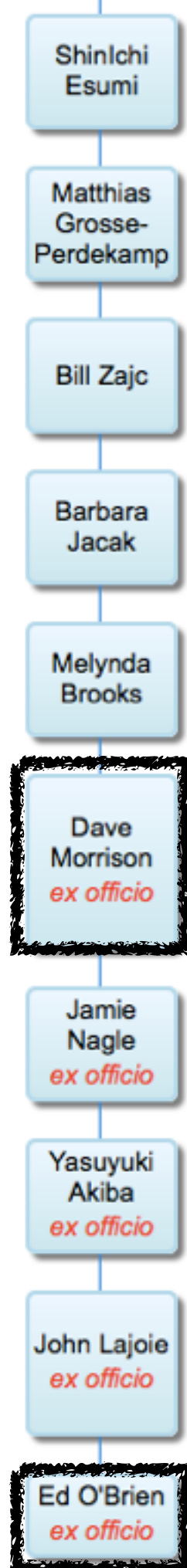
**Extra slides**

# BNL contributions to PHENIX publications

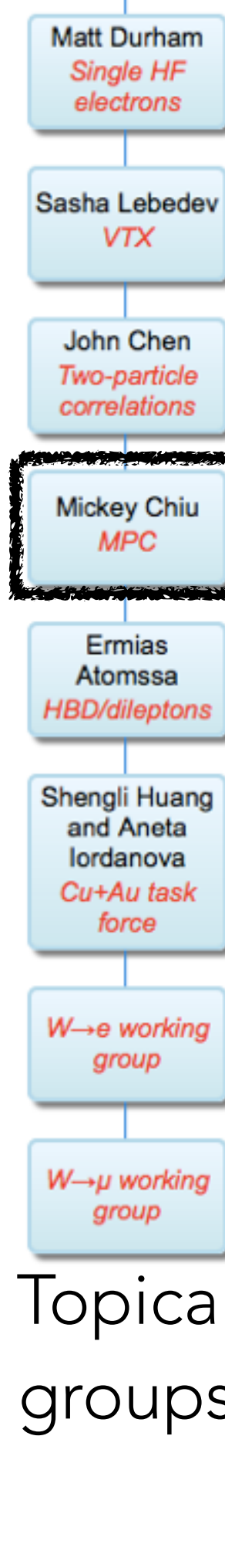
- 1) Cold-nuclear-matter effects on heavy-quark production at forward and backward rapidity in d+Au collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., Phys Rev Lett 112(2014) 252301
- 2) Centrality categorization for  $R_{p(d)+A}$  in high-energy collisions, A. Adare et al., arXiv:1310.4793, submitted to Phys Rev C
- 3) System-size dependence of open-heavy-flavor production in nucleus-nucleus collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., arXiv:1310.8286, submitted to Phys Rev C
- 4) Heavy-flavor electron-muon correlations in  $p+p$  and  $d+Au$  collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., Phys RevC89(2014)034915
- 5) The PHENIX Forward Silicon Vertex Detector, C. Aidala et al., Nucl. Inst and Meth. A755(2014)44
- 6) Measurement of transverse-single-spin asymmetries for midrapidity and forward-rapidity production of hadrons at  $\sqrt{s} = 200$  GeV and 62.4 GeV, A. Adare et al., arXiv: 1312.1995, submitted to Phys Rev D
- 7) Transverse-energy distributions at midrapidity in  $p+p$ ,  $d+Au$ , and  $Au+Au$  collisions at  $sNN = \sqrt{62.4 - 200}$  GeV and implications for particle-production models, S.S. Adler et al., Phys Rev C89(2014) 044905
- 8) Azimuthal-angle dependence of charged-pion-interferometry measurements with respect to 2nd- and 3rd-order event planes in  $Au+Au$  collisions at  $sNN = \sqrt{200}$  GeV. A. Adare et al., Phys Rev Lett 112 (2014)222301
- 9) Concept for an Electron Ion Collider (EIC) detector built around the BaBar solenoid. A. Adare et al., arXiv:1402.1209
- 10) Inclusive double-helicity asymmetries in neutral pion and eta meson production in  $\vec{p} + \vec{p}$  collisions at  $s = \sqrt{200}$  GeV, A. Adare et al., Phys Rev D90(2014)012007
- 11) Nuclear matter effects on  $J/\psi$  production in asymmetric Cu+Au collisions at  $sNN = \sqrt{200}$  GeV, C. Aidala et al., arXiv:1404.1873, submitted to Phys Rev C
- 12) Measurement of  $Y(1S+2S+3S)$  production in  $p+p$  and  $Au+Au$  collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., arXiv:1404.2246, submitted to Phys Rev C
- 13) Comparison of the space-time extent of the emission source in  $d+Au$  and  $Au+Au$  collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., arXiv:1404.5291, submitted to Phys Rev Lett
- 14) Measurement of long-range angular correlation and quadrupole anisotropy of pions and (anti)protons in central  $d+Au$  collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., arXiv:1404.7461, submitted to Phys Rev Lett
- 15) Heavy-quark production and elliptic flow in  $Au+Au$  collisions at  $sNN = \sqrt{62.4}$  GeV, A. Adare et al., arXiv:1405.3301, submitted to Phys Rev C
- 16) Measurement of  $K_S^0$  and  $K^*_0$  in  $p+p$ ,  $d+Au$ , and  $Cu+Cu$  collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., arXiv:1405.3628, submitted to Phys Rev C
- 17) Centrality dependence of low-momentum direct-photon production in  $Au+Au$  collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., arXiv:1405.3940, submitted to Phys Rev C
- 18) Low-mass vector-meson production at forward rapidity in  $p+p$  collisions at  $s = \sqrt{200}$  GeV, A. Adare et al., arXiv:1405.3260, submitted to Phys Rev D
- 19) Cross Section for  $bb^-$  production via dielectrons in d+Au collisions at  $sNN = \sqrt{200}$  GeV, A. Adare et al., arXiv:1405.4004, submitted to Phys Rev C
- 20) Cross Section and Transverse Single-Spin Asymmetry of  $\eta$  Mesons in polarized  $p+p$  Collisions at  $s = \sqrt{200}$  GeV at Forward Rapidity, A. Adare et al., arXiv:1406.3541, submitted to Phys RevD
- 21) "Closing the Door for Dark Photons as the Explanation for the Muon g-2 Anomaly", arXiv:1409.0851

# BNL in PHENIX organization chart

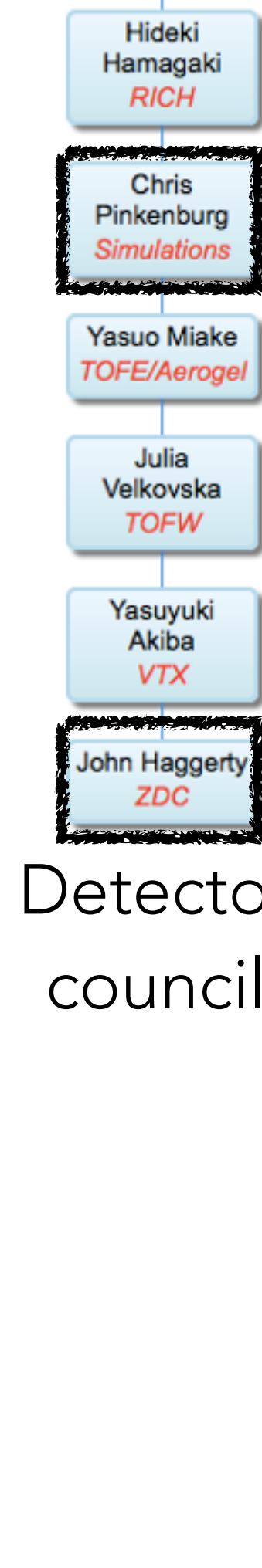




Executive  
council



Topical  
groups



Detector  
council



# Technology Transfer of Medical Imaging Instrumentation Developed in Conjunction with Detector R&D for Nuclear Physics

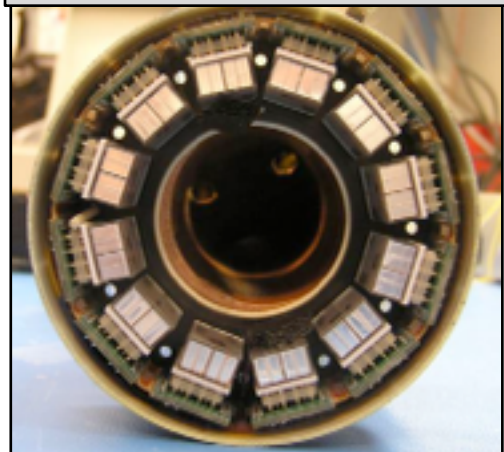
## Pre-Clinical

### RatCAP



**Awake animal brain  
Imaging**

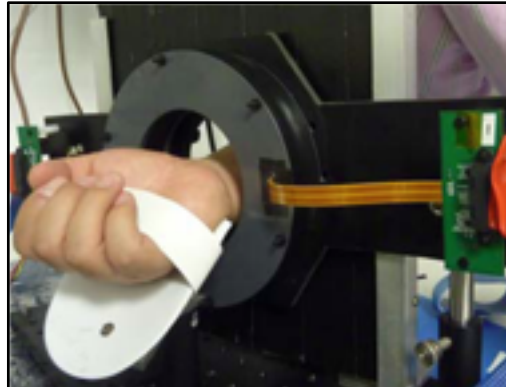
PET Insert for small  
animal MRI



**Simultaneous PET/MR  
brain imaging of small  
animals**

## Clinical

### Wrist PET



**Non-invasive  
quantitative PET for  
drug development**

### Breast PET/MRI



**Simultaneous PET/MR  
imaging of the human  
breast for cancer  
detection**

- A number of medical imaging detectors have been developed at BNL over many years in conjunction with our ongoing detector development program for nuclear physics
- Members of the PHENIX Group (C.Woody, M.Purschke and Sean Stoll) provided major input
- This technology is now being commercialized by a private startup company



***SynchroPET***

- SynchroPET is a new startup biotech company based on Long Island
- Licensed the medical imaging technology and three patents developed at BNL and is currently involved in tech transfer
- Plans to commercialize and market four medical imaging detectors developed at BNL